A June 20, 2013 eruption of solar material shooting through the Sun's atmosphere. The coronal mass ejection hurled millions of charged particles outward. INL's full-scale power grid can reveal how geomagnetic disturbances affect critical power system components. Photo courtesy: NASA's Solar Dynamics Observatory

Illuminating results: INL broadens understanding of solar storms

By Craig Wise & Misty Benjamin, *INL Communications & Governmental Affairs*

A solar flare ejected from the surface of the sun propels charged particles into space that sometimes collides with the Earth's magnetic field. These solar storms, or coronal mass ejections, can and have caused significant damage to critical infrastructure and left millions without electrical power for some time.

Until recently, effects of the geomagnetic disturbances caused by solar storms on critical power system components had not been tested on a full-scale, realistic power grid. Sponsored by the Department of Defense's Defense Threat Reduction Agency (DTRA) and in collaboration with Scientific Applications & Research Associates Inc. and Baylor University, researchers at Idaho National Laboratory modeled and validated these phenomena, confirming some geomagnetic storm theories and bringing new concerns to light.

INL's Test Bed facilities allow scientists to replicate conditions electric utilities experience from geomagnetic disturbances.

"INL's tests not only confirmed industry model predictions of potential power interruption and equipment damage, they also revealed several unexpected secondary effects capable of causing significant impairment," said Scott McBride, INL Power Systems program manager. "Over the past decade, many researchers have modeled and evaluated damage caused by geomagnetic disturbances; however, most of these models and predictions have not been validated in real world conditions.

"Recently, INL and DTRA used the lab's unique power grid and a pair of 138kV core form, 2 winding substation transformers, which had been in-service at INL since the 1950s, to perform the first full-scale testing to replicate conditions electric utilities could experience from geomagnetic disturbances."

The research team found high levels of power line harmonics created during the simulated solar event and how these harmonics impacted power transmission and distribution equipment.

INL's tests demonstrated that geomagnetic-induced harmonics are strong enough to penetrate many power line filters and cause temporary resets to computer power supplies and disruption to electronic equipment, such as uninterruptible power supplies. An uninterruptable power supply provides immediate protection to electronic equipment to ensure it isn't damaged by an unexpected shutdown. Damage to these backup systems could lead to injuries, fatalities, serious business disruption or data loss.

Chris Beck, Vice President of the Electric Infrastructure Security Council, addresses the attendees of INL's Geomagnetic Disturbance Workshop in August 2013.

"We tested the impact of up to 120-amp shot of DC current for 8 seconds over 120 times through the transformer's ground to replicate historically recorded ground-induced currents from previous geomagnetic disturbance events," said Dr. Mack Grady, professor of electrical and computer engineering from Baylor University, who contributed to the INL tests. "This produced losses of the transformer's excitation power. The losses were in excess of 75 percent, which is 60 to 100 times greater than normal, which could cause a rapid rise in the transformer's core temperature. The DC current and the harmonics generated caused significant vibrations that we heard as a loud humming. The noise was caused by severe levels of second and third harmonic currents in the deeply saturated transformer core."

As the first laboratory to obtain this information, INL organized its first-ever Geomagnetic Disturbance Workshop, inviting subject matter experts and thought leaders to see the test results.

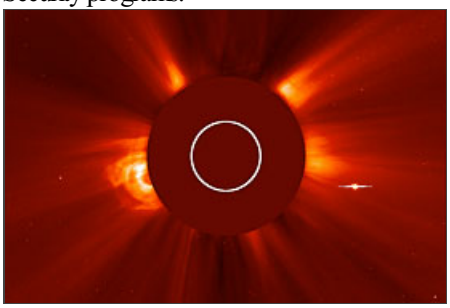
In late August, INL electrical researchers shared unique empirical data from the testing that

demonstrated the ground-induced currents generated by geomagnetic disturbances have the power to disrupt and possibly destroy electrical transformers, the backbone of our nation's utility grid. The workshop also covered many other aspects of geomagnetic disturbances. Speakers from government, academia and industry sectors presented a comprehensive view of issues associated with prediction, protection and regulation of the U.S. electric grid from this phenomenon.

Internationally known keynote speakers included Dr. Bill Murtagh of the National Oceanic and Atmospheric Administration's (NOAA) Space Weather Prediction Center and Dr. Chris Beck, vice president of the Electric Infrastructure Security Council.

"We hosted the workshop to provide information to key stakeholders where they could openly discuss how utilities and regulators might overcome the potentially disastrous effects of solar activity," said Jane Gibson, manager of INL's Infrastructure Security programs.

"Researchers and engineers have long understood that the sun can release enormous magnetic fields. When aimed toward Earth, those fields have caused significant disturbances to the electric grid," said Murtagh. "The INL workshop and the lab's real test data provided an open forum to explore the next steps for predicting and responding to these occurrences."



This image from NASA's Solar and Heliospheric Observatory reveals the coronal mass ejection from a June 20, 2013 solar flare.

One such event occurred March 13, 1989, when a solar storm's particle wave reached Earth. The disturbance took less than two minutes to knock out the Quebec power grid serving more than 6 million customers. Following the 1989 event, utility companies and government agencies around the world realized solar storms can have disastrous effects on power and communication systems.

Using historical astronomical data, a National Academy of Sciences report estimates that a worst-case storm could have an economic impact of $1 trillion to $2 trillion in the first year, which is 20 times the damage caused by a Katrina-class hurricane; however, the National Academy of Sciences and others have built their estimates using digital prediction models.

"Education to increase awareness and willingness to address the problem of solar activity is one of the primary needs of utilities companies and legislators," said Beck. "INL's Geomagnetic Disturbance Workshop brought experts together for some frank discussions and necessary progress toward mitigating the effects of ground-induced currents and other consequences of GMDs."

News of INL's Geomagnetic Disturbance Workshop has already begun to cause ripples with policymakers. On Dec. 6, 2013, INL presented to its findings at the DuPont Summit in Washington, D.C., hosed by the Policy Studies Organization. Additionally, INL hosted a half-day version of the Geomagnetic Disturbance Workshop one day prior to the summit, providing information on the INL tests to congressional staff.

"Skepticism stemming from multiple prediction models has created schisms between members of the electrical community," said Chuck Manto, chief executive officer of Instant Access Network who attended the workshop. "Experts, like the ones gathered for this workshop, have opposing theories about how ground-induced currents should be addressed. The real, hard data from INL has helped to bring everyone to the table."

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Feature Archive